SCIENCE FOR GLASS PRODUCTION

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LASER CUTTING OF FLOAT GLASS DURING PRODUCTION

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Studies were conducted to determine the strength and thermal stability of samples of glass with edges obtained by cutting a moving ribbon of float glass by mechanical and laser cutting. The advantage of laser cutting was demonstrated.

Brittleness is a problem in using sheet glass. The weakest part of the glass sheet is the edges due to the large number of gross stress concentrators that remain in the edges after cutting the moving ribbon and keeping the degree of its hazardousness unchanged over the entire time of shipment, storage, and use of the glass [1].

Mechanical cutting (as the simplest and most accessible) is used in continuous production of sheet glass; it consists of making a median crack with a hard-alloy roller. In order to obtain a quality edge, i.e., a defect-free edge and smooth, shiny end with perpendicular surfaces, the optimum cutting parameters must be rigorously observed. Otherwise, the edge will have a coarse shape with a large number of chips and pits. The transverse bending strength and thermal stability are quantitative criteria for evaluating the quality of the glass edge.

Mechanical cutting reduces the strength of the glass by 60% on average. The strength of such glass can be increased by treating the edges. The most common method is mechanical (grinding followed by polishing). However, the strength of the glass increases by approximately 30% [2].

A laser cutting unit (Fig. 1) for separating the edges from the moving glass ribbon has now been introduced in the ÉPKS-4000 float line (Saratov Glass Institute Co.). The method of controlled thermal cleavage is used in the unit, and it essentially consists of projecting the beam of a molecular gas CO_2 laser, which provides for local heating (to 350 – 450°C) of the cutting line, and feeding an air-water mixture under pressure on the surface of the glass. As a result of the temperature gradient that arises at a small depth from the surface of the glass, a microtrack is formed and causes separation.

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The edge is separated after the glass ribbon is transversely cut into sheets of the required length with edge cutters. The ends of samples obtained after laser and mechanical cutting of a float-glass ribbon are shown in Fig. 2.

The qualitative evaluation with a MIN-8 (× 50) microscope showed that both ends are smooth and shiny. However, although a defect-free edge is obtained after laser cutting,

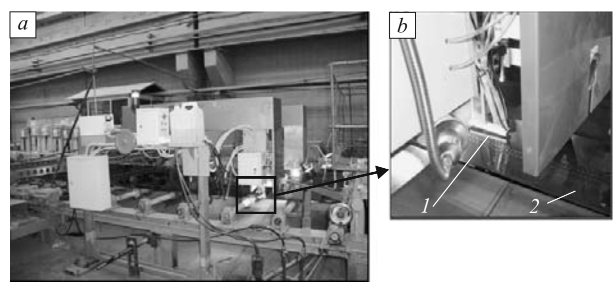

Fig. 1. Laser cutting unit (*a*) and unit for applying the cutting line (*b*): *1*) site of application of laser cutting on the glass ribbon; *2*) glass ribbon.

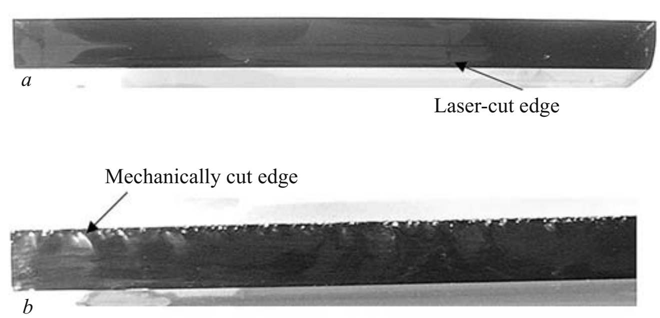

Fig. 2. Edges of glass samples (from the end) after laser (*a*) and mechanical (*b*) cutting.

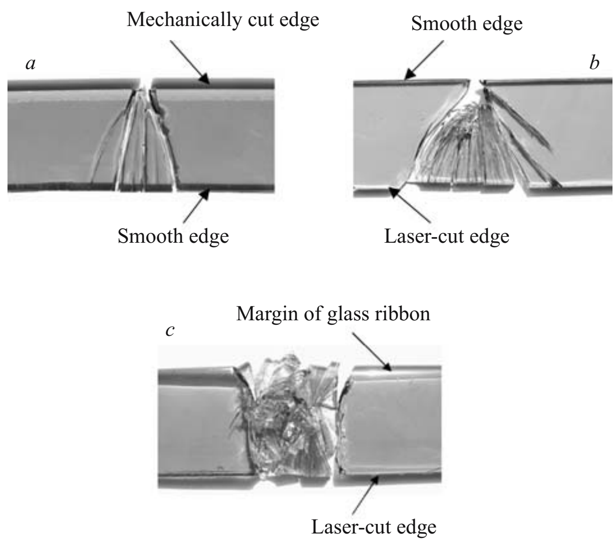

Fig. 3. Character of fracture of glass samples in testing for transverse bending: *a* and *b*) samples with mechanically cut and laser-cut edges; *c*) edge of glass ribbon with laser-cut edge.

"saw teeth" 0.05 – 0.30 mm deep are observed after mechanical cutting. In addition, the surface of the edge has pits and chips whose size is a function of the cutting parameters (roller sharpening angle, pressure on it, etc.) and determines the transverse bending strength of the glass [2, 3].

We conducted preliminary studies to determine the strength and thermal stability of samples of glass with different types of edges. The strength was determined by three-point transverse bending on a GMS-20 tensile-testing machine using a special attachment. Batches of glass samples with edges obtained by mechanical (mechanically cut edge) and laser (laser-cut edge) cutting. An edge obtained as a result of breaking opposite the cut edge (smooth edge) was used as the control.

The glass was cut so that the investigated and smooth edges were on the same surface. In the transverse bending test of the laser-cut edges, fracture always began from the smooth edge, i.e., the laser-cut edge was stronger than the smooth edge. To evaluate the strength of the samples with a laser-cut edge, the samples selected had one margin which was the margin of the edge of the glass ribbon. In this case, fracture always began from the surface of the glass.

The data in Table 1 show that the glass samples with different kinds of edges had different transverse bending strength. The strongest was the laser-cut edge: it was approximately 5 times stronger than the edge obtained as a result of mechanical cutting and 1.5 – 2.5 times stronger than the smooth edge. The edge obtained in cutting a glass ribbon 6 mm thick with the laser was stronger (by approximately 1.3 times) than the edge obtained in cutting glass 4 mm thick. This difference can be attributed to the different rate of movement of the glass ribbon: 338 m/h for the glass 4 mm thick and 234 m/h for the 6-mm glass, i.e., the glass 6 mm thick remained exposed to the laser beam for a longer time.

The different strength of the samples can be judged by the character of their fracture as a result of transverse bending (Fig. 3). The glass samples fractured with formation of branching cracks of the "herringbone" type and fracture began from the weaker edge, i.e., the edge with a defect on the smooth edge. The margins of the laser-cut glass fractured with the appearance of a system of cracks on the surface of the glass, i.e., fracture began from a defect away from both edges, which is only characteristic of some materials, sitals, for example [4].

The thermal stability was determined by vertical loading of heated samples of glass in cold water. In testing the cut edge investigated, the other edges and ends were covered. In determining the thermal stability of the surface of the glass, all edges and ends of the sample were covered to eliminate the effect of the periphery.

As the data in Table 1 show, samples with a mechanically cut open edge had the lowest thermal stability. As noted, the mechanically cut edges for performing these tests were obtained with the optimum cutting parameters, as otherwise (if large pits and chips were present), the thermal stability decreased to 80°C.

The thermal stability of the glass samples with a bare laser-cut edge was on the level of the thermal stability of the surface. In testing samples with an uncovered mechanically cut edge, fracture began from the cut, while it began from the

TABLE 1

Tested surface	Transverse bending strength, MPa			Thermal stability, °C		
	average	minimum	maximum	average	minimum	maximum
			Glass 4 mm thick			
Edge:						
smooth	56.4	11.2	76.8	149.2	146.0	150.0
mechanically cut	16.4	10.1	24.0	105.5	103.0	108.0
laser cut	79.2	28.4	158.1	148.8	142.0	157.0
			Glass 6 mm thick			
Surface of sheet	38.2	27.9	73.9	144.7	135.0	153.0
Edge:						
mechanically cut	18.7	5.1	32.0	116.3	107.0	119.0
laser cut	104.3	66.5	168.1	143.0	142.0	147.0

smooth edge for the laser-cut samples and the cut edge remained undamaged (Fig. 4).

The thermal stability of sheet glass with an edge obtained by cutting it with a laser was thus 30 – 35% higher than a mechanically cut edge, which is especially important for heat-absorbing glass.

The studies showed that use of a laser to cut a moving ribbon of glass decreases the effect of the edge effect and has a number of advantages over traditional mechanical cutting; the main ones are reported below:

No damage to the surface of the glass sheets by glass chips. In addition to the basic (median) crack), lateral cracks appeared in cutting the glass with a glass-cutting roller, and in certain conditions, they could go out onto the surface of the glass and form chips during fracture or later (for example, in finished sheets in a pile). In falling on the surface of the glass, the glass chip damages it, which reduces the strength of the glass. In laser cutting, there are no chips.

Decrease in rejects on cutting. Deviation from the optimum parameters during mechanical cutting of the glass ribbon can result in sheets with a coarse edge, breaking not along the cutting line or in general the absence of a break, i.e., the glass is rejected. In addition, there are losses of glass in readjustments to change the sheet size, in replacing the glass-cutting rollers, in changing to another type of glass, etc. Eliminating these causes will increase the yield of acceptable sheets of glass.

Reduction of breakage in shipping glass sheets. In shipping glass sheets (in containers or boxes), the sheets can be deformed and break. The periphery of the sheet is usually the center of genesis of a crack. The absence of chips on the edges of the sheets after laser cutting will make it possible to eliminate the danger of their breaking during shipment.

Possibility of strengthening the surface of sheet glass during production. Strengthening of glass articles during their processing is now widely used. One reason that strengthening of the glass ribbon has not been used in industry is the difficulty or impossibility of cutting the strengthened glass by the traditional mechanical method. In addition, even in cutting a strengthened glass ribbon, the danger of the sheet's breaking due to the weak periphery persists, so that it is believed that sheet glass should be strengthened after cutting. The problem of strengthening the surface of the glass during continuous production can be successfully solved by using a laser for cutting the moving glass ribbon.

Simplification of preparation of the surface of the glass before applying film coatings. In production of glass with different coatings, the requirements for the quality of its surface are high [5]. In mechanical cutting of a glass ribbon, kerosene or other propping fluid is used; it spreads, and it is difficult to remove traces along the periphery of the sheets. For this reason, before applying coatings on the glass sheets, special methods of preparing the surface must be used, which complicates the manufacturing process and makes the finished product more expensive, while no propping fluid is used in laser cutting.

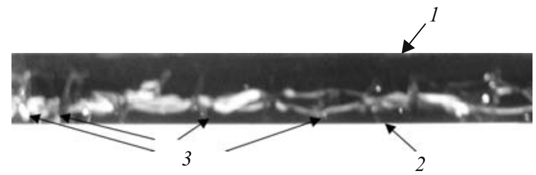

Fig. 4. Character of fracture of the end of glass sample in determining thermal stability: *1*) laser-cut edge; *2*) smooth edge; *3*) cracks.

Elimination of mechanical treatment of the periphery of the sheets. Before heat treatment (soft-glass molding, quenching), the edges of the glass sheets are subject to mechanical processing. Since a defect-free (strong and thermostable) edge is formed as a result of laser cutting, additional processing of the periphery of the sheets is not required.

Increase in reliability of construction articles made of sheet glass. Sheet-glass articles are exposed to different mechanical loads during use, including bending loads. When a peripheral zone with a defective edge is loaded, it can cause the entire article to break (for example, double glass panes).

During use, construction articles made of sheet glass can be exposed to not only mechanical but also to thermal loads. In temperature drops when the field of the glass sheet is much hotter than its edges in the sash, thermal stresses arise. Cracks usually appear, going from the edge of the sheet, and this can cause the entire article to break. This especially relates to heat-absorbing glass, which becomes 25 – 30°C hotter than colorless glass in the same conditions. Increasing the strength and thermal stability of the periphery of glass sheets will increase the strength and lifetime of the entire article.

The use of a laser for cutting sheet glass during continuous production thus has an inarguable advantage over mechanical cutting due to the increased strength and thermal stability of the periphery of the finished sheets of glass.

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